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REMOVAL OF WATER SUPPLY CONTAMINANTS - NITRATE :
TECHNICAL LETTER NO. 17

Subject: Technical Letter 17 — February 1977
Removal of Water Supply Contaminants -- Nitrate

This is the third in a series of technical letters dealing with state of the art methods for removal of contaminants from water supplies so that the supply will be in compliance with state and federal drinking water standards.

Contaminant

This technical letter is concerned with nitrate as a contaminant of drinking water. In 1976 the State Environmental Protection Agency (EPA) reported five groundwater supplies scattered around the state which exceeded the nitrate standard of 45 milligrams per liter (mg/l). The levels found range from 110 to 66 mg/l. In addition there are a number of surface water supplies which may exceed the limit at certain periods of the year due to runoff from agricultural uses of nitrate.

Prevalence and Uses

Nitrates are found in water supplies due to leaching from underlying geological deposits, runoff from farmland, percolation through soils fertilized with nitrogen, aerobic breakdown of previously contaminated waters, and contamination from agricultural and industrial waste. Contamination can also occur from septic tanks and other similar sources of waste.

Soluble nitrates are used extensively as fertilizers. These soluble nitrates can easily be leached or washed from the soils. Nitrates are also used in preserving meats, in medicine, and in the manufacture of gunpowder and other explosives. Nitrite, which is readily oxidized to nitrate, is used as a preservative in foods and in the manufacture of dyes. Nitric acid is widely used in the production and manufacturing of a wide variety of products. The spent wastes from these processes contain large amounts of soluble nitrates. Nitrates are also produced naturally by bacteria during the aerobic breakdown of organic nitrogen-containing wastes, i.e., plant and animal material.

Health Effects

Primary health concern with nitrates is based on their effect on very young children, particularly infants 1 year old or less. In the digestive system of the very young, conditions exist which allow for the reduction of nitrate to nitrite. The nitrite absorbed from the stomach can react with hemoglobin to form methemoglobin. Methemoglobin does not have the oxygen carrying capacity of hemoglobin. This results in an oxygen deficient condition known as 'blue baby' disease. The condition is reversible once the source of nitrate is removed; however, the effects can range from minor to fatal depending on the severity and length of the cyanotic condition.

Nitrates rarely are a problem for older individuals except at extremely high levels. These levels would never be reached in waters unless large quantities of soluble nitrates were discharged directly into the water.

Maximum Levels

The maximum level of nitrate for drinking water is 10 mg/1 as N or 45 mg/1 as NO_3^-.

Removal

Nitrate salts are highly soluble so removal of nitrate cannot be obtained using processes which depend on precipitation of insoluble compounds such as lime-soda softening or coagulation. Since nitrate exists in water as a negatively charged ion, techniques which are capable of removing negatively charged ions should be applicable to nitrate removal. There are no removal processes which are specific for nitrate, so treatment can be expensive depending on general water quality.

A. Ion Exchange

1. Anion Exchange

At the present time only ion exchange techniques have been found useful for reducing the nitrate level. Anion exchange resins are used to remove the nitrate by replacement with chloride. Most anion exchange resins have a higher selectivity for removing sulfate rather than nitrate so that the level of sulfate in the water is an important factor in the efficiency of the system. The presence of sulfate does not inhibit the removal of nitrate but greatly decreases the resins' capacity for nitrate removal, thereby requiring more frequent regeneration of the system.

Although sulfate is the major species which interferes by competing with the nitrate, other elements also interfere. Iron Interferes by clogging the resin. Waters with high iron require pretreatment to remove the iron before removal of nitrate. Silica also interferes by adsorption onto the resin. The adsorbed silica physically prevents the nitrate from being exchanged. With high silicon levels, pretreatment of water is necessary for efficient operation of the exchanger.

The major operating costs for the system are the costs of the salt for regeneration and waste brine disposal. Costs are about $0.12 to $0.22 per 1000 gallons treated based on 1976 costs. This does not include the costs of any pretreatment which might be required. The disposal of the waste brine can account for as much as 50 percent or more of the total costs of nitrate removal treatment. Costs may change as additional experience is gained from supplies using this process.

2. Demineralization

If the chloride level in the finished water becomes too high, it might be necessary to use a dual bed resin and completely demineralize the water. The dual bed resin contains a cation exchanger bed and an anion exchanger bed. The cation exchange resin removes all positively charged species by replacement with hydrogen ion. The anion exchange resin removes all negatively charged species by replacement with hydroxide ion. The hydrogen ions from the cation exchanger combine with the hydroxide ions from the anion exchanger to produce water. The cation exchanger is regenerated with strong acid, and the anion exchanger is regenerated with caustic. The demineralized water may be blended with untreated raw water to obtain an acceptable level of nitrate. If blending fs not done, the finished water must be treated to adjust pH and hardness to prevent corrosion of the distribution system.

B. *Reverse Osmosis*

Reverse osmosis involves the removal of soluble minerals by passage of water through a semipermeable membrane. To get water to pass through the membrane it is necessary to apply pressure to the water containing the minerals to overcome the natural direction of flow which would be for pure water to diffuse into the mineral-containing water. The amount of pressure necessary is dependent on the mineral content of the raw water. Although reverse osmosis can be used to reduce the nitrate level, its application is impractical and costly unless it is already in use for the treatment of brackish water. The most significant cost is plant construction. For a 1000 cubic meter per day plant (183 gpm)» construction costs are about $250,000 based on 1976 costs. This cost does not include any costs for interest during construction, site and site improvement, discharge facilities, storage and delivery facilities, or any special treatment. Operating costs are about $18,000 for a plant of that capacity.

C. *Electrodialysis*

Electrodialysis involves the removal of salts by means of ion selective membranes and a d.c. current to assist transport of the ions across the membrane. There is depletion of ions on one side of the membrane if current is passed for any length of time, while there is concentration on the other side of the membrane. Any level of desalting can be achieved by increasing the residence time or increasing the current density.

For efficient operation good water pretreatment is required. This should include coagulation of colloidal particles, oxidation of iron and soluble organics, carbon filtration, and finally acidification.

Although this process can be used for the reduction of nitrate levels, its application is impractical and costly even if other contaminants are to be removed unless the equipment is already in use or planned for use to reduce brackish water to an acceptable salt level. The cost of electrodialysis is dependent on the level of contaminant to be reduced. In general it will be more costly than reverse osmosis. The pH of the effluent may require adjustment to protect the distribution system.

D. *Distillation*

Distillation involves the volatilization of water to separate it from all dissolved or suspended materials which are not volati1ized. Normally the water is heated under pressure to improve the thermal efficiency of the method by recovering some of the heat. This process produces water of very low dissolved solids. Since the water is corrosive to the distribution system, it is necessary to increase the salt content. This can normally be accomplished by appropriate blending of the finished water and the raw water to a nitrate level below the allowable level.

Some pretreatment of the feed-water may be necessary. Most often only deaeration is necessary, but in some situations it may be necessary to remove suspended solids and calcium and magnesium to prevent scaling.

Distillation is a relatively expensive and impractical solution for the removal of specific contaminants from water. The process involves the removal of a large volume of water from a small amount of dissolved material. This results in an unfavorable energy requirement since it is essentially independent of the contaminant level and only dependent on the amount of water to be treated. The major cost is plant construction which will be about $1.2 million for a 1000 m^3/day plant (183 gpm). The operating costs for energy are also high, since there is only partial heat recovery in this process.

General Comments

All of the removal techniques discussed above require pilot-scale testing for a specific application to determine their efficiency. Pilot-scale studies are also needed to determine what, if any, pretreatment is necessary to insure good operating efficiency. All of the processes which effectively demineralize the water require some adjustment of pH and/or hardness and alkalinity to prevent corrosion of the distribution system.

Very truly yours,

Dr. Francis Amore

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